The Inflation Probe: A Probe-Class Astrophysics Mission[1]

SCIENCE DRIVERS: The Cosmic Microwave Background (CMB) radiation consists of a bath of photons emitted nearly 14 billion years ago, when the universe was in its infancy. Inflation models predict a stochastic background of gravitational waves should leave a faint polarized signal in the CMB, which can be detected and characterized with modern polarization-sensitive instruments. A convincing detection of the resulting distinctive "B-mode" signature would provide a measure of the amplitude of gravitational waves emitted during a primordial inflationary epoch [2,3]. Such a detection and spectral characterization would confirm the inflationary paradigm and identify the energy scale at which inflation took place, revealing fundamental physics at energy scales impossible to achieve in any terrestrial laboratory. In addition, a cosmic-variance limited measurement of the entire sky over a wide range of frequencies and angular scales will enable the use of CMB lensing as a probe of large scale structure; provide a definitive determination of the epoch of reionization; characterize astronomical foregrounds; measure neutrino masses; and potentially reveal insights to new physics beyond the Standard Model.

TECHNICAL CAPABILITIES: The Inflation Probe mission will be critical in order to make full-sky, uniformly well-calibrated and interconnected maps, to minimize systematic errors, and to avoid atmospheric effects. Multiple frequency bands (including some inaccessible from the ground) are required to maximize both sensitivity and foreground rejection, especially Galactic emission. The development of this mission stands in the context of plans for the next stage in ground-based observations for which the CMB community is optimizing mapping speed and sensitivity at frequencies accessible across available atmospheric windows to produce maps of the CMB. A satellite mission is unique in its ability to study large spatial scales with complete spectral coverage for removing polarized foregrounds. As has historically been the case, ground-based, sub-orbital, and orbital experiments are highly complementary [4]. Overlap in angular and frequency coverage will be essential for consistency in calibration and systematic control between these complementary approaches, as will a robust exchange of technological developments and analysis techniques, as well as joint analysis of final data products.

A design study will clearly be required to refine the Inflation Probe mission in light of new data from Planck and ground-based observations. Representative mission capabilities to address the proposed science include: $\sim 10^4$ dual polarization radiometric sensors with spectral coverage spanning approximately 30 to 300 GHz, a cold telescope with ~10 arc-minute or better angular resolution at 100-200 GHz, and a survey operational mode (*e.g.*, see [5]) in order to achieve a cosmic-variance limited measurement of the entire sky over a wide range of frequencies and angular scales in the presence of astrophysical foregrounds.

NEED FOR PROBE-CLASS MISSION: The consensus view of the U.S. community is that the appropriate choice for the Inflation Probe CMB polarization surveyor is a Probe-Class mission (between $250M - $1B) [6]. The specific implementation should be studied for presentation to the 2020 Decadal Review to refine and update the mission cost model. In conjunction with this effort it will be critical to take into account the scientific capabilities of other space-based CMB polarization opportunities (e.g., JAXA and NASA MO Litebird [7], NASA Midex [8], and ESA M-class missions [9]).

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1 *A White Paper by the Inflation Probe Science Interest Group (IPSIG) submitted in response to the "Cosmic Origins Program Analysis Group Call for White Papers: Probe-Class Astrophysics Mission Concepts" [1].*

NEW TECHNOLOGIES: Specific instrumentation challenges to implement the Inflation Probe mission are summarized in the "2015 PCOS Program Annual Technology Report (PATR)". The CMB Technology Roadmap ranked detector arrays as the highest priority, recommending a development strategy that utilizes detector systems in sub-orbital and ground-based polarization experiments. Significant progress has been made with a variety of detector approaches including antenna-coupling via planar transmission-line, micro-machined waveguide, and absorber-coupled filled array structures. We briefly summarize the key technologies identified for the Inflation Probe and their readiness [10]:

· **Advanced millimeter-wave focal plane arrays for CMB polarimetry (Current TRL ~4):** Arrays of detectors with background-limited sensitivity, dual-polarization detection capability, and control over systematic errors in multiple wavebands spanning centimeter to millimeter wavelengths are required to enable foreground removal for the Inflation Probe. The detectors must demonstrate high efficiency over a wide spectral range, be scalable to realize the required focal plane sensitivity, and be amenable to instrument architectures for space by allowing appropriate electromagnetic shielding, cosmic-ray immunity, and noise stability. Kilo-pixel scale detector arrays are operating in ground-based CMB polarization experiments. Balloon experiments presently operate such detector systems in a radiation environment analogous to that encountered in space.

· **Millimeter-wave optical elements (Current TRL ~2-5):** High-throughput telescope and optical elements with controlled polarization properties are required for the Inflation Probe. These optical systems require broadband millimeter-wave filters, coatings, and polarization control components as well as infrared thermal blocking filter technologies.

· **High-efficiency cooling systems for temperatures covering the range 20K to below 1K (Current TRL ~6):** Reliable and efficient continuous systems are needed for the Inflation Probe; these must have high thermal-lift capacity and be able to operate continuously. Cooling power must be increased beyond that provided by the Planck system to enable the use large of large focal planes. Approaches based on adiabatic demagnetization refrigeration (ADR), 3He sorption cooling, or closed-cycle dilution offer viable avenues to provide the desired capabilities.

REFERENCE – Selected Source Material

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